DOCUMENT RESUME

ED 118 462 SE 020 362

AUTHOR	Venkata, Subrahmanyam S.
TITLE	Professional Engineering Education in India.
PUB DATE	16 Jun 75
NOTE	21p.; Paper presented at the Annual Meeting of the American Society for Engineering Education (Colorado State University, Ft. Collins, Colorado, June 16-19, 1975); Occasional marginal legibility
EDRS PRICE	MF-$0.83 HC-$1.67 Plus Postage
DESCRIPTORS	*Curriculum; Educational Programs; *Engineering Education; Engineers; *Higher Education; *Instruction; Professional Education; Program Descriptions
IDENTIFIERS	*India

ABSTRACT

All asPects of professional engineering in India are discussed, including the structure of basic, technical and professional education, the pattern of engineering curriculum, the role of professional societies, the role of industries, and recommendations and conclusions. Comparisons are made between these aspects and those now existing in the United States. (MLH)

PROFESSIONAL ENGINEERING EDUCATION IN INDIA

by

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Presented in the 1975 ASEE Annual Meeting held in Colorado State University, Fort Collins, Colorado, on June 16, 1975 in the Session: Professional Engineering Education in Foreign Countries.

INTRODUCTION

India has witnessed a radical change in scientific and technological developments in the past decade. The underground nuclear explosion and the recent launching of a space satellite are clear testimonies of these developments. India is able to export not only the industrial products from tiny pins to sophisticated computers, but also technical know-how to scores of other countries. All around the world, and especially in the Mid-eastern countries, Indian Engineers are being hired to responsible positions. Many African countries are receiving sizeable educational and industrial assistance from India. There are a vast number of Indian Engineers in the U.S. appointed to responsible positions. Some of these are without any formal education to speak of in U.S.*

These achievements are partly due to the dramatic changes in the educational patterns in the past decade, especially in engineering education. The philosophy of engineering curricula has changed totally from the classical British pattern of technological approach of the 1950's to the American pattern of scientific approach in the 1970's. To the author's knowledge, nowhere have such significant changes taken place in such a brief time span.

Inspite of these glorious facts, recent engineering graduates are frustrated in their profession. The main reason for this is that their jobs do not put to full use their abilities or the education they have obtained. Many of the industries are not innovative and hence do not employ newer approaches in hiring and using the services of the indigenous graduates. Also, the industries lean heavily on foreign expertise and

*It is not surprising to learn that India stands third in the world in terms of scientific and technical manpower.

do not offer exciting and challenging jobs to young engineers. Due to these reasons there is a brain drain of young engineers to foreign countries. In recent years, though, India has recognized the need for proper evaluation of manpower and interaction between educational institutions and the industries. This was due to the surplus engineering graduates in the country during the late 1960's, resulting in the massive unemployment of these highly respected professionals. Indian engineers are by no means inferior to their contemporaries around the world as far as their intellectual capabilities are concerned. Even so, engineering education in India is not without its pitfalls. This paper, in the course of its development, intends to look into the credit and debit sides of professional engineering in India.

The central purpose of this paper is to look into all aspects of Professional Engineering in India. After defining a professional engineer in India, it will be followed by the structure of basic, technical and professional education, the pattern of engineering curriculum, the role of professional societies, the role of industries and recommendations and conclusions. Throughout the paper an attempt will be made to compare these various aspects with those existing now in the U.S.

In the recent past, two excellent papers[1,2] have looked into engineering education in India with particular emphasis to electrical engineering. They are worth looking into. Other related articles[3-14] are also cited in the end under references.

DEFINITION OF A PROFESSIONAL ENGINEER

A Professional Engineer today in India is more a technologist, who is defined as "a person holding a degree of equivalent professional qualification, who is responsible for the application of scientific knowledge and method to Industry".

Earlier, as a technologist, an engineer was more a doer than a thinker.[2] He was trained for maintenance-type jobs and because of the wide variety of jobs he was called upon to perform, the average graduate was required to have a knowledge of all the branches of engineering. British influence and their educational pattern were responsible for this situation.

Since obtaining Independence in 1947, India has recognized the need for creative engineers and it has changed its educational patterns suitably in the past 28 years. The professional engineer today is becoming more cretive than being purely a theoretician. He uses his scientific and technological background to perform the available practical jobs in various modern industries. He is still a technologist, though, in the context of the above definition.

STRUCTURE OF BASIC EDUCATION

Before entering a college, most Indian students go through one of two following types of precollege or high school education:[1]

(1) Ten years of schooling (eleven years in certain regions) leading to a secondary school certificate, followed by a one-year pre-university course or a one-year pre-professional course or a two-year intermediate course.

(2) Eleven years of schooling for the higher secondary school certificate (twelve years in certain regions).

Like engineering education, the basic school education is undergoing constant revision. It is envisaged that a standard pattern of a eleven-year or twelve-year schooling would evolve under this revision, which is to comprise of 4 or 5 years of primary or elementary school education, a middle or junior-high school state of 3 years and a higher secondary or high school stage or four years.

It is appropriate to state here that the basic school education is taught in the regional language of the states. There are about 15 major regional languages recognized in India. English is taught as a second language in these schools. There are some schools which offer English as a medium of instruction even at this level. However, at the college level, the medium of instruction was English till 1970, at which time several states introducted their regional language as the medium of instruction for liberal arts programs. Engineering education has been in English only and this trend is likely to continue into the forseeable future at least.

STRUCTURE OF ALL TECHNICAL EDUCATION

Technical education is classified into three main groups depending upon the level of educational training one has to undergo. These are:

a) Certificate programs and vocational and industrial training: One who gets this type of training in an industrial (vocational) institute in India is a Craftsman.[3] He is a skilled worker possessing the broad range of rquired skills upto a pre-determined standard in a specific occupation.

b) Diploma Courses: A diploma per se in India implies specifically on associate degree in the appropriate branch of engineering. A person who undergoes this type of training is called Technician,[3] who is a person qualified by specialist technical education and practical training, whose work requires the application of technical knowledge and skill higher than those of a skilled worker and lower than those of a technologist. An institute which confers this type of diploma is called a "Polytechnic". There are about 280 of these in India.

c) Engineering degree programs including graduate and research programs: As mentioned in the previous section, a person who gets a bachelor's degree or its equivalent is called a Technologist or a Professional Engineering. Several of the Indian Engineering schools do offer graduate programs leading to Master's degree after 2-year academic training. Presently, a few of the schools offer Ph.D. programs, too. Since the main theme of this paper is about Professional Engineering the rest of the paper would deal with Bachelor's degree education only. The detailed discussions on other groups of technical education defined above is not within the scope of this paper.

STRUCTURE OF PROFESSIONAL ENGINEERING SCHOOLS

Engineering Colleges in India can be grouped into three distinct Categories[1];

(a) Higher Technological Institutions

(b) Regional ~~Engineering~~ Colleges and

(c) Engineering Colleges supported by State Government or private agencies.

The Higher Technological Institutions offer the best possible educational facilities. Under this category there are six Indian Institutes of Technology (IIT's) located at Khangpur, Bombay, Madras, Kanpur, Varanasi, and Delhi. They have been established with substantial support from various western countries. For example, the IIT at Kanpur was set up by a consortium of nine American universities.

These Institutes together with the Indian Institute of Science at Bangalore command the best possible facilities, faculty and resources in the country. Admission to these schools is extremely competitive. Freshmen are selected based on their relative performance in a nation-wide joint entrance examination. This is equivalent to scoring high in SAT scores in the USA. Each of these institutes is autonomous and formulates its own curriculum patterns and academic policies.

There are at present about fifteen Regional Engineering Colleges. They are joint ventures of Central (Federal) Government and the connected State Government. Some of these have received substantial aid from the U.N. under UNESCO. They are equivalent to Engineering Colleges in State Universities in the USA. Admission into these colleges is also very stringent and the seats are offered on a competitive basis.

The other engineering colleges operate as colleges affiliated to Universities, which are either public or private. Admission to these colleges is less competitive.

Since the engineering profession in India being highly valued in society, only the top 10 per cent of the high school graduates can enter any engineering college.

For the admission into engineering degree programs, a special study of mathematics, physics and chemistry at the high school level is a requirement.

Engineering degrees in India are conferred as Bachelor of Engineering (B.E.), Bachelor of Technology (B. Tech.) and Bachelor of Science in Engineering (B.Sc.(Engg)). There is not much difference in these degrees as the names might suggest. In the '60's, some engineering schools offered 3-years program and others 4-year programs after thirteen years of schooling. In the '70's almost all the institutions are offering 5-year programs after 12 years of primary and secondary education. All the three degrees are recognized as equivalent to B.S. in the appropriate branch of Engineering in the U.S.

All the engineering schools which are about 136 in number require recognition by University Grants Commission, an autonomous body set up by the Federal Government. The other responsibilities of this body are to fund research programs, offer fellowships and scholarships, etc. like NSF in the U.S.

STRUCTURE OF ENGINEERING CURRICULUM

It has been established in the preceding section that the undergraduate degree in India in most of the schools is of 5 years duration. A core curriculum covering mathematics, the physical sciences, and basic engineering subjects like workshop practice and engineering graphics are common to all students majoring in all branches of engineering graphics are common to all students majoring in all branches of engineering during the first three years (first two years in some institutions). The last two years are devoted to a particular branch of specialization which the student chooses as his major.* The more popular branches like Civil, Electrical and Mechanical Engineering are offered by almost all institutions in India. Many schools offer Chemical Engineering as a major. More recent branches like Industrial Engineering, Aerospace Engineering, Textile Technology, etc. are offered by a handful of universities in the country.

As Murthy[1] has mentioned, the factors to be taken into account in forming a curriculum are the needs of the country, modern developments in technology and the needs to emphasize the fundamental and the general

*Appendices A and B show typical curricula in Civil and Engineering respectively followed in India. For the sake of comparison the respective West Virginia University's (WVU) curricula are also shown.

at the expense of the purely topical, empirical or vocational. During the past 20 years many universities have been periodically revising the curriculum to achieve the best compromise among the factors adumbrated above. Most of the curricula have been changed from the old British pattern to the more scientific pattern of the U.S. Practical emphasis is also given even today as in workshop training and laboratory work. In the U.S., workshop training is obtained by most of the students during their pre-college days. Many universities have adopted or are in the process of changing over to the semester pattern of education and have discontinued the system of organizing courses in units of one academic year duration. In the process of this changeover, most universities have not kept abreast of one another. It is almost certain that all universities will eventually follow the semester system. Some other features introduced during the last two decades are the additions of humanities courses in the core curriculum; and at the senior level, a senior project (see the Appendices). In this, a student can demonstrate his ability in terms of designing and executing a project. Given the proper facilities, environment and support, the execution of his/her project often turns out to be one of the most meaningful and valuable phases of the overall training of the student. Even seminars have been introduced in the senior year in most of higher technological institutions in recent times. Though a lot of flexibility has been introduced in the course content and syllabus, a student is not free to choose the courses he likes since no such choice is available. He has to take the courses as set forth by the university for the entire five years except for a few electives in the senior year. Another point of difference with the American system is that the Indian system has no prerequisites for advanced level course. The introduction of computer programing has changed the Indian curriculum significantly. But this is to be found only in the IIT's which are equipped with modern computers. Most other schools lack proper computing facilities; but even these schools teach Fortran Programming so as to prepare the modern student to handle his new job effectively. Even with these dramatic changes in the curriculum pattern, the Indian educational system places emphasis on the technological compatibility details than on designing as in American universities.

The examination pattern in most of the engineering schools remain as in the past, which is very rigid and strait for the present. Examinations are not given by the instructor who teaches a course but question papers for them are usually given by a professor from another university. The answer papers are valued by yet another professor from a different university. This way, the instructor of the course has no control over the grading procedure. Similarly, homework assignment has no contribution in student grading. However, points for classwork (about 20%) count for grading in some schools, and this the only way the instructor can influence the grades of his students. In this respect the author feels that Indian institutions should emulate American patterns of examinations where a faculty member is in complete charge of not only examinations but also the course content itself and the syllabus.

FACULTY EXPERTISE

The quality of any engineering education, for that matter, education depends to a major extent on the quality of faculty expertise. Just as the curricula has witnessed dramatic changes in the past two decades, the level and quality of faculty has improved cognately. Twenty years ago, a Ph.D. faculty member was rare to find in engineering institutions. Today not only in the IIT's and in the Regional Engineering Colleges, but also in most of the other universities, there are numerous well-qualified Ph.D.'s among the faculty.

Teachers of the present day are innovative and eager to improve their teaching methods and methodologies and are mainly responsible for the curriculum changes of the past years. An engineering professor is no longer the second-class citizen of a decade ago and his salary today is on par with those holding first-class civil service jobs. Most universities follow their own methods of selecting or promoting a faculty member as there is no national standard for this. In many of the older institutions, praticularly in those run by State Governments, staff promotions are governed by Civil service rules, seniority, years of experience and other factors. However, in newer institutions, faculty positions are filled through selection by appropriate committees of internal and external applicants. This process is supposed to select teachers competent in teaching, research and development. Since research is given priority in many higher technological institutions, teaching sometimes suffers. This is because a young teacher interested in advancing his career tends to neglect teaching. This is probably true in most of the institutions in the U.S. In the past, research was almost unheard of in India, but of recent funded research has been going on in the IIT's and some other institutions. Also, unfunded research is being carried on in many of the schools.

<u>What was the Central Government's Contribution to Improve Teaching Quality?</u>

Fifteen years ago the Central Government started a program called Technical Teachers Training Fellowship Program. Under this program, bright B. S. graduates were selected and they would spend 2-3 years in selected institutions where under the supervision of senior and experienced faculty, they were trained in teaching. Simultaneously, they were required to obtain master's degree. Some were pursuing Ph.D. degree in places where opportunity was available. After the training period, these trainees were recruited to faculty positions in various schools. During the early 1970's, the Central Government established four regional Technical Teachers' Training Institutes in the various parts of the country. These were founded to avoid sending graduates to various engineering institutions for training under the above cited program and also to achieve uniform standards in training of engineering teachers. These institutes presetly offer 1-2 years training leading to the degree of Bachelor of Technical Education (B.T.Ed).[4] In recent years, the Central Government has initiated what are known as Quality Improvement Programs for engineering faculty. Under this program, teachers from some schools are sent to selected institutions abroad to pursue a doctoral degree and upon returning were to teach at their home institutions.

THE ROLE OF PROFESSIONAL SOCIETIES

There is no society like the Natinn Society of Professional Engineers in U.S. which controls and regulates the engineering profession by the EIT and P.E. Examinations and by careful screening of engineers for Board registration. In India, an engineer holding a Bachelor's degree is considered automatically to be a Professional Engineer. Only the architectural engineer is required to register with the city in which he intends to set up his practice. Before he can register, though, he needs to get appropriate training under a registered professional architectural engineer.

Institution of Engineers (India) is the major society for engineers concerned about their profession and its progress. This society has many major divisions which are Civil, Electrical, Mechanical and others. Each of these divisions can be compared to ASCE, IEEE, ASME and other respectively, though not in size. The Institution publishes journals with articles of interest to professional engineers and teachers. It also holds several meetings at various places, enabling engineers to exchange their ideas and know-how. To the author's knowledge, the journal published by the Civil Engineering Division is one of the most circulated journals in the world.

Those who are engaged in engineering activities and without a formal engineering education or degree can obtain what is known as Associate Member of Institution of Engineers (A.M.I.E.) by passing examinations equivalent to EIT and PE examination. This is considered equivalent to a B.S. degree for employment purposes only. By offering these examinations the institution enables a greater number of people to qualify as Professional Engineers.

The society equivalent to the American Society of Engineering Education (ASEE) is called the Indian Society of Technical Education (ISTE)[2]. This was formed recently in 1969 and aims to serve as a forum for technical teachers to interact and enhance their professional competence, to formulate national policies on technical education and to advance the cause of technical education in general. Since its inception this society has been running Summer Institute Programs for engineering teachers with the help of the National Science Foundation to enable teachers without graduate degrees to obtain them and others to advance their technical knowledge and competence. It is estimated that approximately 25 per cent of the total teaching community in engineering colleges have participated in the program.

ROLE OF INDUSTRIES

There are two kinds of industries in India: Public-sector owned by Central and State Governments; and private sector which are investor-owned. Both these types of industries employ a large number of engineers trained in India. But these jobs do not offer enough challenge and responsibility to the engineers working there and there is a lot of frustration among them. The industries are still wary of the ability of the engineering graduates and the schools which produce and train them, and hence, lean heavily on foreign expertise.[2] So they do not provide enough opportunity for native engineers to prove themselves, which has resulted in many engineers leaving their jobs to hold better and more challenging jobs abroad. This situation has to change if there is to be progress through self-sufficiency. What is needed is a good program of interaction between the industries and the educational institutions so that students may be trained specially to suit the needs of the industires planning to employ them. Schools should also revise their curricula to suit industrial needs and demands. Hence, this interaction has to work both ways if it is to be successful and effective.

CONCLUSIONS AND RECOMMENDATIONS

Professional Engineering in India has progressed impressively in the last 20 years and has produced responsible, creative engineers. A great deal of time and money has been invested in establishing top grade schools and programs. But the results from these programs have not been proportionate. Before embarking upon further investment of time or money, the schools must carefully consolidate what has already been achieved. The schools need to train their engineers to suit professional needs after evaluating the situation realistically. There are several innovative programs that could be introduced with a little investment. One of them is the Co-op programs[5] which have been successful in the U.S. for the last few years. It is encouraging to note that many people are thinking along innovative lines and have shown preference for newer concepts like the Open University,[6] proper interaction between universities and industries, etc. which are positive steps toward the progress of engineering education.

The curriculum also needs periodic revision and updating so as to keep in pace with industrial progress, and to suit the local, national and societal needs. The quality of teaching, faculty expertise and the physical facilities in schools must be modernized periodically. Schools have a paramount role to play in research and development by introducing innovations in methodologies of technology and engineering. Audio-visual aids (whatever is available) should be given primary importance in classroom teaching. The Personalized System of Instruction[7] could also be introduced. These are more successful teaching methods than the classical blackboard teaching method. The examination system needs radical revision, so that examinations will not be looked upon by a student as a Doomsday Course, but as a necessary step in the process of learning. The pressures of one examination at the end of an academic year can be alleviated by the introduction of quizzes (one-hour tests), technical papers, course projects and other innovative techniques. Emphasis on graphics must be laid so that the young engineer can learn the art of proper report-writing. An important aspect lacking in engineering education both in India an in the U.S. is the emphasis on technical communication in terms of writing. This must be introduced even at the undergraduate level. A uniform standard is to be attained in all facets of education.

The role of any university is to teach the fundamentals, to acquaint the student with the principles of engineering science and scientific methods and to train them to confront and solve new problems that they may encounter. The typical Indian graduate is conscientious, well-disciplined, well-drilled and hard working. But he should approach any problem with a positive attitude, realizing that he is playing an important role in the development of his country. He should do his work with dedication and learn to identify himself with the people and their problems. He should think of himself as a practical engineer and must be able to assume leadership easily and not be diffident.

One of the drawbacks in the past has been lack of communication between the student and his teacher. Faculty should encourage active student participation in classes and it must be realized that learning is a two-way process. Students must be given a chance to evaluate their learning methods and importance must be given to student remarks on faculty, teaching methods, curriculum and the like.

The aim of any education is to produce individuals who would benefit the society. In this respect, the engineering schools have an added responsibility of training engineers to be of maximum benefit to society. For this, the universities should develop bilateral relationship with the industries, both in private and public sectors. Collaterally, Industries should encourage Indian engineers and offer them responsible and challenging jobs. The industries should also disclose their technical problems and man-power needs to the schools. In this respect the Central Government can play an important role as a liasion between the schools and the industries and help to achieve meaningful progress in engineering education. This, in turn, would benefit the country and its people. It may be worthwhile to set up a body, commission or board to act on behalf of the government to see that both schools and industries work cooperatively and exchange necessary information desirably. To an extent the council of Scientific and Industrial Research (CSIR) fills this gap.

English would continue to be the medium of instruction for the forseeable future, especially for professional engineering education. This is an absolute requirement today, though it should be recognized that one day regional languages would be adopted. This is possible only when the lexicongraphy of engineering of these languages has reached the minimum required level.

The professional education pattern in India should eventually be structured with that the future Indian graduates would be capable of playing a leading role not only in the development of India but also play a leading role in the industrialization of several developing countries.

ACKNOWLEDGEMENTS

The author is thankful to Drs. W. W. Cannon and W. J. Wilhelm for giving him the opportunity to write and present this paper. He is grateful to Drs. S. H. Advani, N. K. Annamalai, H. V. S. Gangarao, A. K. Mallik, A. V. Peddada, S. Yusuff, and several other Indian graduate students to West Virginia University for their useful input to this paper. Finally, he owes a lot to his wife, Mrs. Padma S. Venkata, who almost co-authored the paper.

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APPENDIX-A

TYPICAL UNDERGRADUATE CURRICULUM IN CIVIL ENGINEERING (C.E.)

INDIA — First three years

Subject	#Courses
Chemistry	4
English	2
Mathematics	5
Physics	3
Engineering Design-Drawing and Graphics	2
Computation	1
Non CE Courses	8
Humanities	3
Economics	2
Workshop	3

INDIA — Last two years

Subject	#Courses
Geology	1
Surveying	1
Soil & Materials	3
Structures	4
Hydraulics & Sanitary	5
Transportation	3
Structures Soil & Mechanics Hydraulics (Electives)	2
Project	2
TOTAL	175-200 Hours

USA (WVU) — First two years

Subject	#Courses
Chemistry	2
English	2
Mathematics	4
Physics	2
Engineering Design	2
Computation	0
Non CE Course (Mechanics)	2
Non-Technical Electives (core)	3
Basic CE Courses	1
Economics	2
Physical Education	2
Geology	1

USA (WVU) — Last two years

Subject	#Courses
Surveying	1
Soils & Materials	2
Structures	3
Hydraulics & Sanitary	3
Transportation	1
Structures Soil & Materials Hydraulics & Sanitary Transportation (Both are tech. electives)	2
Engineering Economy	1
Seminar	1
Project	1
TOTAL	135 Hours

APPENDIX-B

TYPICAL UNDERGRADUATE CURRICULUM IN ELECTRICAL ENGINEERING (E.E.)

INDIA — First three years

Subject	#Courses
Chemistry	3-4
English	1-2
Mathematics	2-5
Physics	3-4
Engineering Design Drawing and Graphics	2
Computation	1
Non EE Courses	6
Humanities	3
Basic EE Courses	1
Economics	2
Surveying	2
Workshop	2-4

USA (WVU) — First two years

Subject	#Course
Chemistry	2
English	2
Mathematics	4
Physics	2
Engineering Design	2
Non EE Courses (Mechanics)	2
Non Technical Electives (Core)	3
Basic EE Courses	2
Economics	2
Physical Education	2

INDIA — Last two years

Subject		#Courses
Networks & Systems		2-3
Electromagnetics		2-3
Energy (Power)		4
Electronics		4-6
Math Elective		1
Communication Control Power Systems Electronics	(Electives)	2-4
Humanities		2
Seminar		1
Project		2
TOTAL		175-200 Credit Hours

USA (WVU) — Last two years

Subject		#Course
Networks & Systems		2
Electromagnetics		2
Energy (Power)		2
Electronics		3
Math Elective		1
Engineering Science Elective (Non EE)		1
Communications Control Power Systems Electronics Computers Biomedical Electromagnetics	(All Electives)	4
Non Technical Electives		3
Seminar		1
Project		1
TOTAL		135 Credit Hours